

Table 1. Covered digesters in North Carolina for flushed swine manure.

Parameter	Units	Barham Farm (Cheng et al., 2004)	Carroll's Farm (Safley et al., 1993)	Vestal Farm (Bull and Worley-Davis, 2005)
Type of Farm	head	4000 sow farrow to wean	1000 sow farrow to finish	9,792 finishers
Live animal weight	lb	1,600,000	1,560,000	1,468,800
Type of flush system		Pull-plug shallow pit	Flush tanks	Flush tanks
Digester volume	ft ³	864,500	935,400	100,800
Digester size	ft	265x265x20	265x265x24	138x138x13.2
Loading rate	lb VS/1000 ft ³ /day	4.32 (measured)	9.3 (design)	65 (design) ¹
HRT	days	176	22.4	25 (design) ¹
Type of digester	Temperature range	Ambient temperature	Ambient temperature	Mesophilic (95 °F ± 3° F) ²
Biogas production	ft ³ /day	33,192 (2003 avg.) Range from <10,000 to > 72,000 (1/1/2003 to 12/31/2003)	28,000 to 30,000 (5/15/1993 to 8/23/1993)	22,000 to 47,000 SCF (8/6/2004 to 8/29/2004)
Biogas production	ft ³ /lb VS loaded	8.89	3.5	Insufficient data
Methane content in biogas	percent	63.7 ± 4.7 ²	68 to 80 percent	Not reported

¹System included a solids-liquid separation tank to concentrate solids so that much of the flushed liquid bypassed the covered digester and went directly to a storage pond. Data was insufficient to determine actual loading rate and HRT.

²Mean ± standard deviation.

farrow-to-finish farm with flush tanks; it was also deeper than a typical lagoon (Safley et al., 1993). The third one was on a 9,792-head finishing farm with flush tanks. It featured a heating system and 6-inch Styrofoam insulation to maintain a constant temperature (Bull and Worley-Davis, 2005). Information for the three projects is listed in Table 1.

Only one of the projects reported gas production over an entire year. The ambient-temperature covered digester for a 4,000-sow farrow-to-wean farm showed a biogas production range of < 10,000 ft³/d to > 70,000 ft³/d, and averaged 33,000 ft³/d with 63.7 percent methane over a one-year period (Cheng et al., 2004). The loading rate was about 4.3 lb VS/1000 ft³/day, which is slightly lower than the recommended loading for the permanent treatment volume in an open anaerobic lagoon, and slightly less than half the maximum loading rate recommended by NRCS (2003a) for covered digesters. However, the loading rate was based on measured flow and influent samples, not on tables for VS production. The average biogas production was 8.9 ft³/lb VS loaded. HRT time for this covered digester was 176 days, which is about four times longer than the minimum HRT (40 days) recommended by NRCS (2003a). The other two projects reported biogas production for only a limited time in the summer and were

in the range of 22,000 to 47,000 ft³/d. The design HRTs of these two projects was about 25 days. The summer gas production from the covered digester reported by Safley, et al. (1993) was only about 3.5 ft³/lb VS loaded (based on design VS loading, not measured loading).

Fixed-film Digesters

Fixed-film digesters are also called attached-growth digesters or packed-bed digesters. Because there are less suspended solids in the dilute wastewater to provide surfaces for bacteria to grow and perform their conversions, adding plastic or other media to the digester allows the bacteria to attach to a surface. Research has been conducted at lab scale at Auburn University in Alabama (Hill and Bolte, 2000) and at N.C. State University (Cheng and Liu, 2002) with fixed-film or attached-growth digesters for flushed swine manure, but no full-scale systems have been used for dilute swine manure. Because the flushed manure is dilute, the wastewater flow rate through the digester is high, and the HRT is small. In the N.C. research with a media specific gravity of 0.98 (media slightly less dense than water) and 35°C temperature, the Chemical Oxygen Demand (COD) and volatile suspended solids reductions were 68